REMARKS

The office action of July 29, 2004 has been reviewed and its contents carefully noted. Reconsideration of this case, as amended, is requested. Claims 1-14, 16-73, 85-89, and 91-97 remain in this case, claims 96 and 97 being added and claims 1, 3, 5, 7, 10, 24 and 91 being amended by this response.

The independent claims have been amended to emphasize the key features of the invention and its novelty over the prior art. No new matter has been added. More specifically, the amendments to claims 1 and 91 are fully supported by the specification on page 9, lines 9-19, page 15, line 27 through page 17, line 20, page 18, lines 1-6, page 19, lines 7-21, page 20, lines 22-23, page 21, lines 1-7, and page 21, lines 18 through page 22, line 6.

Figures 1-6, 9-10, 15-24, and 26-32 have also been amended in this response. More specifically, the cross-hatching of the active region in each of the figures has been removed. This was done to remove any potential confusion between the active region and the tilted optical mode. The cross-hatching of this region in the original figures was diagonal, and, as such, could be confused with the schematic representation of a tilted optical mode. No new matter has been added.

As a general comment, the Applicant respectfully emphasizes the main principal features of the invention, which makes the invention novel over the prior art. The tilted cavity semiconductor laser disclosed in the patent application is designed such that there exists a tilted optical mode, which is termed "the resonant optical mode", having the minimum losses due to the leakage of the optical power, or in other words, due to radiation. The selection of such a mode is governed by the intersection of the dispersion curve for the tilted optical modes in the cavity, on the one hand, and the dispersion curve for the reflectivity of the reflector, on the other hand. For most of the embodiments, there exists only one fixed tilt angle and only one fixed wavelength of light such that, the optical mode propagates within the cavity at this tilt angle and this fixed wavelength. At the same time, the reflectivity of the reflector for the tilted optical modes has its maximum just at the same wavelength. Such an optical mode has the minimum losses among all tilted optical modes. The losses through the bottom reflector, the losses through the top reflector, and the losses through the side facets contribute to the total losses. Thus, the

resonant optical mode is a tilt optical mode having a certain tilt angle of propagation and a certain wavelength. Thus, the tilted cavity laser disclosed in the present application emits laser light in this resonant optical mode having a certain fixed tilt angle of the propagation of light within the cavity and a certain fixed wavelength. Thus, the tilted cavity laser disclosed in the present application operates as a wavelength–stabilized laser.

These features of the disclosed tilted cavity laser are clearly stated in the present application. In particular, "[a]lso, a wavelength-stabilized laser is realized for edge-emitters. The wavelength stabilization is due to the difference in the dispersion laws for the tilted optical modes in layers having different refractive indices. " (present application, page 3, lines 14–16).

Further, it is stated "[i]f the cavity comprises at least two layers having different refractive indices, the resonant conditions in both materials stabilize both the wavelength of emitted light and the tilt angle of the optical mode. Alternatively, wavelength stabilization is realized if the cavity is just a single layer surrounded by multilayered interference mirrors. Resonant conditions in both the cavity and the layer of the multilayered mirror having a different refractive index from that of the cavity stabilize both the wavelength of emitted light and the tilt angle of the optical mode. In another embodiment, the optical mode is used to exhibit the total internal reflection at the boundaries between the two semiconductor layers. The interplay between the radiative losses through the bottom and the top mirror, on the one hand, and through the side surface, on the other hand, stabilizes the wavelength of emitted light. " (present application, page 9, lines 9–19).

The description of the embodiment of Fig. 8 states that "Fig. 8 displays the radiative losses close to the minimum of α_{rad} as a function of the wavelength. Bars correspond to different lateral modes of the cavity. The figure displays the spectral range where

$$\alpha_{rad}^{\min} \leq \alpha \leq 2\alpha_{rad}^{\min} . \qquad (15)$$

A rather narrow spectral range of $\approx 14\,\mathrm{nm}$ demonstrates the possibility of efficient stabilization of the wavelength of the emitted light." (present application, page 18, lines 1–6).

The description of the embodiment of Fig. 10, where the cavity is composed of two parts, states "[r]esonance conditions of Eqs. (17a) or (17b) yield two equations for unknown wavelength λ and the wave vector component k_x. Thus, the optical mode is uniquely defined. " (present application, page 20, lines 8–10).

The description of the embodiment of Fig. 15 states that "Fig. 15 shows another embodiment of the present invention, in which an absorbing element (1517) is placed on top of the top multilayered reflector (210), and an absorbing region (1518) is placed within the absorbing element (1517). Thus, the multilayered reflector (210) provides the selection of the wavelength, at which the losses are minimum. Light transmitted through the top reflector (210), is absorbed by the absorbing region (1518). The absorbing region (1518) absorbs light transmitted through the reflector (210) to provide light output in the lateral direction. The light (1519) comes out of the laser through the side surface of the cavity, the laser thus operating as a wavelength-stabilized edge-emitting laser. " (present application, page 20, line 27, through page 21, line 6).

In addition, although the Applicant is not submitting a declaration at this point, the Applicant is submitting a Supplemental Information Disclosure Statement along with this response. The Applicant respectfully requests that the Examiner note that the present invention has since been published in these well-known and respected journals. The invention has received notoriety as an important and novel discovery. This is evidence of the novelty of the invention and that it is widely regarded as groundbreaking technology. The references also illustrate the long-felt need for this technology. Those of ordinary skill in the art recognize the importance of the discovery. In addition, as a general matter, these reference act as further evidence that the work in the application is enabling. The Applicant believes that this evidence stands, on its own, without the need for a declaration. The Applicant would request the opportunity to file a declaration, if the Examiner is not convinced of the notoriety and import of publication within these specific journals and invitations to the conferences regarding this invention. The Applicant would also appreciate the opportunity to schedule an interview, either telephonic or in person, with the Examiner, if an interview would further prosecution of the application.

The numbered paragraphs below correspond to the numbered paragraphs in the Office Action.

Double Patenting

3. The Examiner stated that if claim 1 should be found allowable, claim 91 will be objected to as being a substantial duplicate thereof. Applicant respectfully disagrees.

"[C]ourt decisions have confirmed applicant's right to restate (i.e., by plural claiming) the invention in a reasonable number of ways. Indeed, a mere difference in scope between claims has been held to be enough.... Nevertheless, when two claims in an application are duplicates, or else they are so close in content that they both cover the same thing, despite a slight difference in wording, it is proper after allowing one claim to object to the other claim under 37 CFR 1.75 as being a substantial duplicate of the allowed claim" (M.P.E.P. 706.03(k)). As amended, claim 1 recites a semiconductor laser. Claim 91 recites a semiconductor device, but does not limit the type of semiconductor device to a laser. Claim 91 is clearly broader in scope than claim 1, since the semiconductor device could be any type of semiconductor device. In addition, since the device in claim 1 is broader in scope, the two claims do not cover the same thing. Claim 1 covers only semiconductor lasers, while claim 91 covers devices including, but not limited to lasers, photodetectors and optical amplifiers. Therefore, the claims are not substantial duplicates. Reconsideration and withdrawal of the objection is respectfully requested.

Rejection under 35 U.S.C. §112, first paragraph

5. Claims 1-14, 16-73, 85-89 and 91-95 were rejected under 35 U.S.C. 112, first paragraph, as failing to comply with the enablement requirement. Applicant respectfully disagrees.

The test for enablement is whether the disclosure, when originally filed, contained sufficient information regarding the subject matter of the claims as to enable those of ordinary skill in the pertinent art to make and use the invention. The standard is whether the experimentation necessary to practice the invention is undue or unreasonable. In re Wands, 858 F.2d 731, 737, 8 USPQ2d 1400, 1404 (Fed. Cir. 1988). See also U.S. v. Telectronics, Inc., 857 F.2d 778, 785, 8 USPQ2d 1217, 1223 (Fed. Cir. 1988) ("The test of enablement is whether one

reasonably skilled in the art could make or use the invention from the disclosures in the patent coupled with information known in the art without undue experimentation.") (emphasis added).

It is further noted that satisfaction of the enablement requirement is not precluded by the necessity of some experimentation, such as routine experimentation. The key word here is "undue" not "experimentation". In re Angstadt, 190 USPQ 214 (CCPA 1976). The fact that experimentation may be complex does not necessarily make it undue, if the art typically engages in such experimentation. In re Certain Limited-Charge Cell Culture Microcarriers, 221 USPQ 1165, 1174 (Int'l Trade Comm'n 1983), aff'd. sub nom., Massachusetts Institute of Technology v. A.B. Fortia, 774 F.2d 1104, 227 USPQ 428 (Fed. Cir. 1985). See also In re Wands, 858 F.2d at 737, 8 USPQ2d at 1404. Indeed, a considerable amount of experimentation is permissible if it is merely routine, or if the specification provides a reasonable amount of guidance to the direction in which the experimentation should proceed. In re Jackson, 217 USPQ 804 (Bd. App. 1982). Thus, the test of enablement is not whether any experimentation is necessary, but whether, if experimentation is necessary, it is undue. In re Angstadt, 537 F.2d 498, 504, 190 USPQ 214, 219 (CCPA 1976).

Further, the specification need not explicitly teach those in the art to make and use the invention; the requirement is satisfied if, given what they already know, the specification teaches those in the art enough that they can make and use the invention without "undue experimentation." Genentech, Inc. v. Novo Nordisk, A/S, 108 F.3d 1361, 1365, 42 USPQ2d 1001, 1004 (Fed. Cir. 1997); In re Vaeck, 947 F.2d 488, 495, 20 USPQ2d 1438, 1444 (Fed. Cir. 1991). Indeed, a patent need not teach, and preferably omits, what is well known in the art. In re Buchner, 929 F.2d 660, 661, 18 USPQ2d 1331, 1332 (Fed. Cir. 1991); Hybritech, Inc. v. Monoclonal Antibodies , Inc., 802 F.2d 1367, 1384, 231 USPQ 81, 94 (Fed. Cir. 1986), cert. denied, 480 U.S. 947 (1987); Lindemann Maschinenfabrik GMBH v. American Hoist & Derrick Co., 730 F.2d 1452, 1463, 221 USPQ 481, 489 (Fed. Cir. 1984).

The tilted cavity laser of the present invention is designed such that there exists a resonant optical mode, in which light within a cavity propagates in a direction, tilted with respect to the direction normal to the lateral plane and with respect to the lateral plane itself. The cavity and the reflectors are selected such that this resonant optical mode has the minimum losses

compared with both the losses of the other tilted optical modes, and with the losses of the optical modes, propagating in the vertical direction, and with the losses of the optical modes propagating in the lateral direction. The total losses of an optical mode in a non–absorbing structure may be regarded as a sum of the radiative losses (or leakage losses) through the bottom reflector, through the top reflector, and through the side facets. The selection of the optical mode having the minimum total losses is based on the particular design of the cavity and the reflectors.

The existence of the selected angle of the selected wavelength is based on the fact that the cavity and the reflectors differ in their refractive indices. Therefore the dispersion relation between the wavelength and the angle for tilted optical modes which can exist in the cavity is different from the dispersion relation between the wavelength and the angle for tilted optical modes, for which the reflectivity of the reflectors is maximum. These two dispersion curves match at a fixed angle and a fixed wavelength. Such an optical mode has the minimum losses for radiation (or leakage) through the reflectors. For example, the Abstract of the Disclosure explains "[a]lso, a wavelength-stabilized laser is realized for edge-emitters. The wavelength stabilization is due to the difference in the dispersion laws for the tilted optical modes in layers having different refractive indices." (present application, Abstract, Lines 11–13). This approach is realized in the embodiments disclosed in Figs. 6 through 12. Particular calculations used in selecting the layer thicknesses and alloy compositions in the prototypes are based on the method described in the cited reference by Born and Wolf. This is specifically disclosed in the present application. "Amplitude reflection coefficients from the bottom and top Bragg mirrors r_{bottom} and r_{top} may be calculated by using the method described in detail in M. Born and E. Wolf, *Principles of Optics* (6th edition, Pergamon Press, (1980) pp. 1-70)." (present application, page 16, lines 5-7).

A particular way of designing a tilted cavity laser having wavelength–selective losses of the optical modes is described in the specification of the present application. "Fig. 2 illustrates schematically the principle of a laser using a tilted optical mode. The device (200) comprises the cavity (220) surrounded by the bottom reflector (202) and the top reflector (210). The cavity (220) includes an active region (107) surrounded by weakly doped or undoped confinement layers (106). The substrate, current spreading layers, metal contacts, and the bias are not shown in this figure for simplicity. Both the bottom reflector (202) and the top reflector (210) are

resonant multi-layered structures exhibiting a high reflectivity in a certain range of angles and wavelengths. " (present application, page 10, lines 6–12).

The definition of the effective angle of propagation ϑ is given in the specification of the present application. In addition, the wave equation for TE optical modes is formulated in the cited reference by Casey and Panish, page 37, Eq. (2.4–28), and described in the present application:

"In a simpler case of Fig. 3 the structure may be treated as a three-layer slab wave-guide. Then, the electric field in a TE optical mode can be described as follows (H.C. Casey, Jr. and M.B. Panish, Heterostructure Lasers, Part A, Academic Press, New York, 1978, pp.34-57)

$$E_y = C_1 \cos(k_x x) \exp[-\kappa |z|], \text{ if } z < 0; \tag{2a}$$

$$E_y = \cos(k_x x)[A \cos(k_z z) + B \sin(k_z z)], \text{ if } 0 < z < D; \tag{2b}$$

$$E_y = C_2 \cos(k_x x) \exp[-\kappa (z - D)], \text{ if } z > D. \tag{2c}$$

The components of the wave vectors k_x and k_z are connected by the dispersion relation in the active region:

$$k_x^2 + k_z^2 = n_1^2 \left(\frac{2\pi}{\lambda} \right)^2, \tag{3}$$

and the attenuation coefficient κ is determined from the dispersion relation in the reflectors:

$$k_x^2 - \kappa^2 = n_2^2 \left(\frac{2\pi}{\lambda} \right)^2. \tag{4}$$

Here λ is the wavelength of the emitted light in the vacuum. Allowed wave vectors k_x may be found by a standard procedure when boundary conditions at $z = 0$ and $z = D$ are imposed.

To analyze different types of optical modes in the cavity, it is convenient to characterize them by the wavelength λ and the angle ϑ as defined in Fig. 2. Then $k_x = \frac{2\pi}{\lambda} n_1 \sin\vartheta$." (present application, page 11, line 13, through page 12, line 7).

The effective angle of the tilted optical modes is defined from the relationship, $k_x = \frac{2\pi}{\lambda} n_1 \sin\vartheta$. For any given optical modes, the specification of the present application gives the definition of the effective tilt angle of the optical mode: "Then $k_x = \frac{2\pi}{\lambda} n_1 \sin\vartheta$." (present application, page 12, line 7).

The way of selecting a tilted cavity laser is described in the present application. This includes selecting the cavity and the multilayered reflectors such in the following way.

> "To calculate the resonant optical mode, which is selected by any given embodiment, one may consider the radiative losses of the tilted optical mode (213),
>
> $$\alpha_{rad} = \alpha_{bottom} + \alpha_{top} + \alpha_{side} , \tag{8}$$
>
> where the losses via the bottom, top, and side surfaces of the structure of Fig. 2 equal:
>
> $$\alpha_{bottom} = \frac{\cos\vartheta}{D} \ln \frac{1}{r_{bottom}} , \tag{9a}$$
>
> $$\alpha_{top} = \frac{\cos\vartheta}{D} \ln \frac{1}{r_{top}}, \tag{9b}$$
>
> $$\alpha_{side} = \frac{\sin\vartheta}{L} \ln \frac{1}{r_{side}} . \tag{9c}$$
>
> Amplitude reflection coefficients from the bottom and top Bragg mirrors r_{bottom} and r_{top} may be calculated by using the method described in detail in M. Born and E. Wolf,

Principles of Optics (6th edition, Pergamon Press, (1980) pp. 1-70)." (present application, page 15, line 27 to page 16, line 7).

The reflection coefficients of light at a tilted, or oblique, incidence, have been calculated in the cited reference by M. Born and E. Wolf, *Principles of Optics* (6th edition, Pergamon Press, (1980) pp. 1-70). This reference was cited in the application and provided in the IDS. More importantly, it is well known in the art. Someone skilled in the art would be able to easily make these calculations.

> "The present invention solves the problem of the requirement for a large number of layers by using an active element designed such that the resonant optical mode is tilted to the mirrors. Since the reflection coefficient of the incident light increases with the tilt angle when light reflects from a single boundary between the two layers, a necessarily high reflection coefficient, for example 0.995, may be achieved from a resonant multilayered mirror having a significantly smaller number of layers than in conventional VCSELs. In particular, if the angle of incidence exceeds the angle of the total internal reflection at the boundary between the two layers, a reflector may comprise a single layer with a refractive index lower than that of the cavity. The laser of the present invention is called a "tilted cavity laser" herein. Specific examples of semiconductor devices using this design include photodetectors and amplifiers.
>
> If the cavity comprises at least two layers having different refractive indices, the resonant conditions in both materials stabilize both the wavelength of emitted light and the tilt angle of the optical mode. Alternatively, wavelength stabilization is realized if the cavity is just a single layer surrounded by multilayered interference mirrors. Resonant conditions in both the cavity and the layer of the multilayered mirror having a different refractive index from that of the cavity stabilize both the wavelength of emitted light and the tilt angle of the optical mode. In another embodiment, the optical mode is used to exhibit the total internal reflection at the boundaries between the two semiconductor layers. The interplay between the radiative losses through the bottom and the top mirror, on the one hand, and through the side surface, on the other hand, stabilizes the wavelength of emitted light." (present application, page 8, line 28 through page 9, line 19).

The general way to select a tilted cavity laser is to select the cavity and the multilayered reflectors such that the dispersion law $\lambda_{cavity}(\vartheta)$ for the optical mode confined in the cavity and the dispersion law $\lambda_{reflector}(\vartheta)$ for the spectral position of the maximum reflectivity of the reflectors match at only one angle and one wavelength. This may be realized in a variety of different embodiments.

For example, in the embodiment of Fig. 6 it is realized by selecting same top and bottom reflectors, selecting for a given angle and a given wavelength the thicknesses of the constituent layers of the reflectors having an optical thickness of an odd number of quarter–waves and selecting the cavity thickness to be equal to an integer number of half ways. (see present application, page 17, lines 6-13). In another embodiment, this is realized by selecting a cavity composed of two parts, as in the embodiment of Fig. 10, where each part of the cavity has the optical thickness equal to an integer number of half–waves only for a fixed angle and a fixed wavelength. (see present application, page 18, line 22 through page 20, line 10).

At the very least, the Applicant provides someone skilled in the art all of the tools necessary to create the semiconductor device of the present invention. Even if some experimentation would be required, it would be routine. Undue experimentation would not be required.

Claims 1-14, 16-73, 85-89 and 91-95 are enabled by the specification, as filed. Reconsideration and withdrawal of the rejection is respectfully requested.

Objection to the Claims

6. Claim 5 was objected to as being of improper dependent form for failing to further limit the subject matter of a previous claim. Claim 5 has been amended to overcome this objection. Reconsideration and withdrawal of the objection is respectfully requested.

Rejections under 35 U.S.C. §102

8. Claims 1-9, 14, 19-23, 63, 85, 91 and 92 were rejected under 35 U.S.C. 102(b) as being anticipated by Applicant's Admitted Prior art. Applicant respectfully disagrees with the rejection.

Figure 1 is described in the present application:

"A prior art surface emitting laser, or more specifically, a vertical cavity surface emitting laser (VCSEL), is shown in Fig. 1. In a surface emitting laser, an active region is generally put into a cavity. An undoped or weakly doped active region is surrounded by n- and p- contact layers, which are generally surrounded by mirrors. The structure is grown epitaxially on a substrate (10). Bragg reflectors are used for the bottom mirror (102). The rest of the VCSEL is an active element.

A current aperture (13) separates an n-doped current spreading layer (14) having a first metal contact (15), from the weakly doped confinement layers (16) surrounding the active region (17). A second current aperture (13) separates the weakly doped confinement layer (16) from a p-doped current spreading layer (18) having a second metal contact (19). The n-doped current spreading layer (14) sits directly on top of the bottom mirror (102). The active element operates under forward bias (11). The active region (17) generates light. Confinement layers (16) serve to provide electronic confinement for the carriers trapped in the active region. The light comes out (112) through the top mirror (110).

The substrate (10) can be formed from any III-V semiconductor material or III-V semiconductor alloy, e.g. GaAs, InP, GaSb. GaAs or InP are generally used depending on the desired emitted wavelength of laser radiation. The n-doped layer (14) must be formed from the material lattice-matched or nearly lattice-matched to the substrate (10), transparent to the generated light, and doped by donor impurities. The n-doped layer (14) is preferably the same material as that of the substrate (10), e.g. GaAs. Possible donor impurities include, but are not limited to, S, Se, Te, and amphoteric impurities like Si, Ge, Sn where the latter are introduced under such technological conditions that they are incorporated predominantly into the cation sublattice and serve as donor impurities.

The p-doped layer (18) must be formed from a material, lattice-matched or nearly lattice-matched to the substrate (10), transparent to the generated light, and doped by an acceptor impurity. The p-doped layer (18) is preferably the same material as the substrate (10), e.g. GaAs. Possible acceptor impurities include, but are not limited to, Be, Mg, Zn, Cd, Pb, Mn and amphoteric impurities like Si, Ge, Sn where the latter are introduced

under such technological conditions that they are incorporated predominantly into the anion sublattice and serve as acceptor impurities.

The metal contacts (15) and (19) are preferably formed from the multi-layered metal structures. Metal contacts (15) are preferably formed from structures including, but not limited to, the structure Ni-Au-Ge. Metal contacts (19) are preferably formed from structures including, but not limited to, the structure Ti-Pt-Au.

The confinement layers (16) must be formed from a material lattice-matched or nearly lattice-matched to the substrate (10), transparent to the emitted light, and undoped or weakly doped. The confinement layers are preferably formed from the same material as the substrate (10).

The active region (17) placed within the confinement layer (16) is preferably formed by any insertion, the energy band gap of which is narrower than that of the substrate (10). Possible active regions (17) include, but are not limited to, a single-layer or a multi-layer system of quantum wells, quantum wires, quantum dots, or any combination thereof. In a case of the device on a GaAs-substrate, examples of the active region (17) include, but are not limited to, a system of insertions of InAs, $In_{1-x}Ga_xAs$, $In_xGa_{1-x-y}Al_yAs$, $In_xGa_{1-x}As_{1-y}N_y$ or similar materials.

Each layer is separated from the neighboring layer by a current aperture (13) that works as a current blocking layer and can be formed from a material including, but not limited to, an Al(Ga)O layer or a proton bombardment layer.

Different designs for the bottom mirror (102) and for the top mirror (110) can be used, as described, e.g. in D.G. Deppe, *Optoelectronic Properties of Semiconductors and Superlattices* (Vol. 10, Vertical-Cavity Surface-Emitting Lasers: Technology and Applications, edited by J. Cheng and N.K. Dutta, Gordon and Breach Science Publishers, 2000, pp. 1-61). Typical designs include, but are not limited to, a multi-layered semiconductor mirror $GaAs/Ga_{1-x}Al_xAs$ for devices on GaAs substrate or a multilayered structure of a quaternary alloy $In_xGa_{1-x-y}Al_yAs$ with alternating composition for devices on an InP substrate.

A disadvantage of using this design is the need to fabricate Bragg mirrors with an extremely large number of layers because there is a very restricted choice of materials

suitable to create Bragg mirror layers. All of the layers must be lattice-matched or nearly lattice matched to the substrate. For GaAs-based VCSELs, these layers are AlAs and $Ga_{1-x}Al_xAs$ alloys. For the emitted wavelength λ=0.98 μm, the difference in refractive indices between GaAs and AlAs is rather small (Δn=0.57), and about 30 periods (60 layers) are needed in a Bragg mirror to reach 99.5% reflectivity (see, e.g., U.S. Patent No. 6,154,480). For InP-based VCSELs, a suitable lattice-matched material is the alloy $Ga_{0.47}In_{0.53}As$ and corresponding quaternary alloys $In_xGa_{1-x}As_{1-y}P_y$ with the composition (x, y) obeying the relation $x = 1 - 0.47(1 - y)$ or quaternary alloys $In_xGa_{1-x-y}Al_yAs$ with the composition $x = 0.53$ and arbitrary y. The difference in refractive indices between the layers is in this case even smaller ($\Delta n \approx 0.3$), and about 100 periods (200 layers) are needed in the Bragg mirror." (present application, page 6, line 15 to page 8, line 26).

Regarding claim 1, the amended claim includes, in part, "c) a cavity located between the bottom reflector and the top reflector; and d) an active region that can emit light; wherein the semiconductor laser can be operated in at least one resonant optical mode, such that: i) light is emitted from the active region; ii) light in the resonant optical mode propagates in the cavity in a direction tilted with respect to both a direction normal to a lateral plane and the lateral plane itself; iii) the resonant optical mode has minimum optical losses compared with optical losses of the other optical modes; and iv) a wavelength and a tilt angle of propagation of the light is stabilized". The prior art discussed with reference to Fig. 1 in the application does not include a cavity and active region, wherein the semiconductor laser can be operated in at least one resonant optical mode such that light in the resonant optical mode propagates in the cavity in a direction <u>tilted</u> with respect to both a direction normal to the lateral plane and the lateral plane itself. Instead, for the embodiment shown in Fig. 1, the resonant optical mode is the vertical mode, in which light propagates within the cavity in the vertical direction, perpendicular to the pn junction plane, or perpendicular to the lateral plane of the epitaxial structure, and comes out (112) in the vertical direction.

The Examiner stated in the present office action that "it is inherent that some of the radiation, produced by the active region within the cavity, propagates in a direction tilted with respect to both directions normal to the lateral plane and the lateral plane itself." (present office

action dated July 29, 2004, page 9, lines 6-9). Applicant respectfully disagrees with this statement.

While it may be accurate that Hanke *et al.* (further discussed below) discloses a light–emitting diode with light emission in all sides, none of the prior art references of which the Applicant is aware, including all of the references cited by the Examiner, disclose a device, where the wavelength of the emitted light is fixed and at the same time the tilt angle of propagation of light within the cavity is fixed and thus the wavelength and the angle of propagation of the light is stabilized, as claimed in both claims 1 and 91. None of the prior art discloses the combination of elements in claims 1 or 91.

The Examiner also stated that "the features upon which applicant relies (i.e., the output of the laser being tilted) are not recited in the rejected claim(s)." (present office action dated July 29, 2004, page 9, lines 13-14). The Applicant respectfully disagrees with this statement. The Applicant is not relying on the output of the laser being tilted; instead, in claim 1 (and claim 91), there exists a cavity and an active region, where the semicondcutor device can be operated in at least one resonant optical mode such that light in the resonant optical mode propagates in the cavity in a direction <u>tilted</u> with respect to both a direction normal to the lateral plane and the lateral plane itself.

For clarification, the Applicant notes that, while the resonant optical mode is a tilted mode, the output laser light of the tilted cavity laser disclosed in the present application may or may not be tilted.

Conventional semiconductor lasers may be divided in two groups. In conventional edge–emitting lasers, the laser light propagates within the cavity in the pn junction plane, and light output is typically through an edge facet and occurs in the pn junction plane as well. In conventional surface–emitting lasers, laser light propagates within the cavity in the vertical direction and the light output occurs in the vertical direction as well. In a tilted cavity laser disclosed in the present application, the laser light occurs in an optical mode having the minimum losses, and such mode as a tilted mode, in which the laser light propagates within a cavity in a direction tilted with respect to both a direction normal to the pn junction plane and the pn junction plane itself. In different embodiments of the tilted cavity laser, various ways of laser

light output can be realized. The laser light may come out in the vertical direction (the embodiments of Figs. 4, 5, 19) in the pn junction plane, or in a lateral direction (the embodiments of Figs. 15, 16, 17, 20, 28, 29, 30), or in a tilted direction (the embodiments of Figs.31, 32). Thus, the output light of the laser is not necessarily tilted.

Therefore, claim 1 is not anticipated by Applicant's admitted prior art. Reconsideration and withdrawal of the rejection of claim 1 is respectfully requested.

Claims 2-9, 14, 19-23, 63, and 85, being dependent upon and further limiting claim 1, should also be allowable for that reason, as well as for the additional recitations they contain. Reconsideration and withdrawal of the rejection of claims 2-9, 14, 19-23, 63 and 85 is respectfully requested.

Regarding claim 91, the amended claim includes, in part, "c) a cavity located between the bottom reflector and the top reflector; and d) an active region that can emit light; wherein the semiconductor device can be operated in at least one resonant optical mode, such that: i) light is emitted from the active region; ii) light in the resonant optical mode propagates in the cavity in a direction tilted with respect to both a direction normal to a lateral plane the lateral plane itself; iii) the resonant optical mode has minimum optical losses compared with optical losses of the other optical modes; and iv) a wavelength and a tilt angle of propagation of the light is stabilized".

The prior art discussed with reference to Fig. 1 in the application does not include a cavity and active region, wherein the semiconductor device can be operated in at least one resonant optical mode such that light in the resonant optical mode propagates in the cavity in a direction <u>tilted</u> with respect to both a direction normal to the lateral plane and the lateral plane itself. Instead, in Fig. 1, the resonant optical mode is the mode, in which light (112) propagates within the cavity in the vertical direction, perpendicular to the pn junction plane, or perpendicular to the lateral plane of the epitaxial structure.

Therefore, claim 91 is not anticipated by Applicants' admitted prior art. Reconsideration and withdrawal of the rejection of claim 91 is respectfully requested.

Claim 92, being dependent upon and further limiting claim 91, should also be allowable for that reason, as well as for the additional recitations it contains. Reconsideration and withdrawal of the rejection of claim 92 is respectfully requested.

9. Claims 1-6, 17, 19-23, 27, 28, 63, 85, 91 and 92 were rejected under 35 U.S.C. 102(b) as being anticipated by Lim *et al.* (5,757,837). Applicant respectfully disagrees.

Regarding claim 1, the amended claim includes, in part, "c) a cavity located between the bottom reflector and the top reflector; and d) an active region that can emit light; wherein the semiconductor laser can be operated in at least one resonant optical mode, such that: i) light is emitted from the active region; ii) light in the resonant optical mode propagates in the cavity in a direction tilted with respect to both a direction normal to a lateral plane and the lateral plane itself; iii) the resonant optical mode has minimum optical losses compared with optical losses of the other optical modes; and iv) a wavelength and a tilt angle of propagation of the light is stabilized". Lim *et al.* does not include a cavity and active region, wherein the semiconductor laser can be operated in at least one resonant optical mode such that light in the resonant optical mode propagates in the cavity in a direction <u>tilted</u> with respect to both a direction normal to the lateral plane and the lateral plane itself, such that the wavelength and the angle of propagation of the light is stabilized.

The Examiner points to Figs. 1, and 15-18 to support his assertion that the elements of claim 1 are disclosed in Lim *et al.* Fig. 1 "illustrates an intracavity quantum well photodetector integrated within a vertical-cavity surface emitting laser 20". (col. 3, lines 59-61). In this embodiment, "light comes out of the bottom surface 70 of the substrate 22. Thus, it is referred to as a bottom-emitting device. The device can also be designed to have light come out of the top surface.... In general, the device operates in a manner that is consistent with existing VCSEL devices.... However, in accordance with the invention, the device is operated in conjunction with the intracavity quantum well photodetector 50. That is, the intracavity quantum well photodetector 50 of the invention provides an improved photocurrent for use in a standard feedback circuit which is used to adjust the laser injection current in a standard manner." (col. 4, lines 34-37, 43-44, 50-56). Fig. 15 adds an air bridge to the structure, Fig. 16 has a ridge waveguide geometry, Fig. 17 has a buried heterostructure design, and Fig. 18 utilizes proton

implantation. None of these figures disclose a device that allows laser light in a resonant optical mode to propagate in a cavity in a direction tilted with respect to both a direction normal to a lateral plane and the lateral plane itself. In addition, these passages do not disclose a device, which provides the emission of light having a certain fixed tilt angle of propagation within a cavity and a fixed wavelength.

In fact, the device in Lim *et al.* is not designed so that it can be operated in a resonant optical mode, where light in that resonant optical mode propagates in the cavity in a direction tilted with respect to both a direction normal to a lateral plane and the lateral plane. Instead, laser light propagates in the direction normal to the lateral plane, and comes out either through the top of the device or the bottom of the device as known in conventional vertical cavity devices (like vertical cavity surface emitting lasers (VCSELs) and vertical cavity photodetectors). The background discusses such conventional VCSELs. "A VCSEL is an injection diode laser where the **laser oscillation** and output **occur normal** to a semiconductor pn junction plane. In edge-emitting laser diodes, the laser oscillation and output occur in the semiconductor pn junction plane." (Emphasis added, col. 1, lines 22-26). This patent does not disclose laser light propagating in a cavity in a tilted direction. Lim *et al.* also does not disclose a device, which provides the emission of light having a certain fixed tilt angle of propagation within a cavity and a fixed wavelength

Therefore, claim 1 is not anticipated by Lim *et al.* Reconsideration and withdrawal of the rejection of claim 1 is respectfully requested.

Claims 2-6, 17, 19-23, 27-28, 63, 85, 91 and 92, being dependent upon and further limiting claim 1, should also be allowable for that reason, as well as for the additional recitations they contain. Reconsideration and withdrawal of the rejection of claims 2-15, 17, 19-23, 27, 28, 63 and 85 is respectfully requested.

Regarding claim 91, the claim includes, in part, "c) a cavity located between the bottom reflector and the top reflector; and d) an active region that can emit light; wherein the semiconductor device can be operated in at least one resonant optical mode, such that: i) light is emitted from the active region; ii) light in the resonant optical mode propagates in the cavity in a direction tilted with respect to both a direction normal to a lateral plane the lateral plane itself;

iii) the resonant optical mode has minimum optical losses compared with optical losses of the other optical modes; and iv) a wavelength and a tilt angle of propagation of the light is stabilized". Lim *et al.* does not include a cavity and active region, wherein the semiconductor laser can be operated in at least one resonant optical mode such that light in the resonant optical mode propagates in the cavity in a direction <u>tilted</u> with respect to both a direction normal to the lateral plane and the lateral plane itself. Lim *et al.* does not disclose a device, where the wavelength and the tilt angle of propagation of the light is stabilized. Lim *et al.* also does not disclose a device, which provides the emission of light having a certain fixed tilt angle of propagation within a cavity and a fixed wavelength.

The Examiner points to Figs. 1, and 15-18 to support his assertion that the elements of claim 91 are disclosed in Lim *et al.* Fig. 1 "illustrates an intracavity quantum well photodetector integrated within a vertical-cavity surface emitting laser 20". (col. 3, lines 59-61). In this embodiment, "light comes out of the bottom surface 70 of the substrate 22. Thus, it is referred to as a bottom-emitting device. The device can also be designed to have light come out of the top surface.... In general, the device operates in a manner that is consistent with existing VCSEL devices.... However, in accordance with the invention, the device is operated in conjunction with the intracavity quantum well photodetector 50. That is, the intracavity quantum well photodetector 50 of the invention provides an improved photocurrent for use in a standard feedback circuit which is used to adjust the laser injection current in a standard manner." (col. 4, lines 34-37, 43-44, 50-56). Fig. 15 adds an air bridge to the structure, Fig. 16 has a ridge waveguide geometry, Fig. 17 has a buried heterostructure design, and Fig. 18 utilizes proton implantation. None of these figures disclose a selection of an optical mode, which has the minimum losses such that this mode is a tilted optical mode, in which light propagates within the cavity in a direction tilted with respect to both a direction normal to a lateral plane and the lateral plane itself, such that lasing occurs just within this tilted optical mode.

In fact, the device in Lim *et al.* is not designed so that light in the resonant optical mode propagates in the cavity in a direction tilted with respect to both a direction normal to a lateral plane and the lateral plane. Instead, light propagates in the direction normal to the lateral plane, as known in conventional vertical cavity devices and comes out either through the top of the device or the bottom of the device. The background discusses such conventional VCSELs. "A

VCSEL is an injection diode laser where **the laser oscillation** and output **occur normal** to a semiconductor pn junction plane. In edge-emitting laser diodes, the laser oscillation and output occur in the semiconductor pn junction plane." (Emphasis added; col. 1, lines 22-26). This patent does not disclose light in a resonant optical mode propagating in a cavity in a tilted direction. Therefore, claim 91 is not anticipated by Lim *et al.* Reconsideration and withdrawal of the rejection of claim 91 is respectfully requested.

Claim 92, being dependent upon and further limiting claim 91, should also be allowable for that reason, as well as for the additional recitations it contains. Reconsideration and withdrawal of the rejection of claim 92 is respectfully requested.

10. Claims 1, 2, 4-13, 18-24, 58-63, 85, 91 and 92 were rejected under 35 U.S.C. 102(b) as being anticipated by Hanke *et al.* (5,973,336). Applicant respectfully disagrees.

The present application is very different from Hanke *et al.* The present application addresses a wavelength–stabilized semiconductor device, while Hanke *et al.* addresses a light–emitting diode having no wavelength stabilization.

In the present invention, lasing occurs in the resonant optical mode, having minimum total losses at a certain wavelength, due to a combined effect of the cavity and the reflectors. The total losses include external losses due to emission of light out of the device, which are minimized for the active mode. On the contrary, the invention disclosed in Hanke *et al.* aims to increase the light emission of radiation out of the device for the active modes.

More specifically, Hanke *et al.* discloses a light emitting diode. A "Light emitting diode (LED) is a semiconductor diode which emits incoherent radiation. LEDs operate on the principle of spontaneous emission resulting from electron hole pair injection and *direct* recombination under forward bias.... Because of the statistical nature of the recombination process between electrons and holes, the emitted photons are in random directions; they result from spontaneous emission processes in contrast to stimulated emission."
(http://materials.usask.ca/server/kasap/Dictionary/L.html, page 3 of 6) A copy of the web page including this definition was included in Applicant's office action response dated February 17, 2004.

The Examiner stated that "the claim limitations fail to limit the claim to being a laser, since the recitation of a semiconductor laser has not been given patentable weight because the recitation occurs in the preamble." (present office action dated July 29, 2004, page 9, lines 18-21). The semiconductor device in claim 1 is now clearly defined as being a laser in the body of the claim.

The patent by Hanke *et al.* discloses one particular art of LEDs, "allowing radiation generated to be guided towards the side faces of the LED by means of a relatively thick waveguide comprised of a transmissive material, specifically in such a way that as many modes as possible can propagate." (Abstract). Many modes, without any wavelength stabilization, are present among the modes propagating in the waveguide of the LED disclosed by Hanke *et al.* <u>There is no wavelength stabilization is Hanke *et al.*</u>

The Examiner states that the claims do not limit "the claim to only producing modes that propagate in the cavity in a tilted direction." (present office action dated July 29, 2004, page 10, lines 6-7). As amended, claim 1 now more clearly defines the resonant optical mode.

Hanke *et al.* increases the emission of radiation. "In order to improve the emission of radiation, an antireflecting layer 7, ... can be provided on the side face." (col. 3, lines 9–11). "The light emission can also be improved by other known measures." (col. 3, lines 12–13).

In contrast, claim 1 of the present invention discloses a semiconductor laser, which is synonymous with the terms diode laser and laser diode. A "<u>[l]aser diode</u> is a semiconductor diode which emits <u>coherent radiation</u>, in contrast to a <u>light emitting diode</u> (LED) which emits incoherent radiation. <u>Laser diodes</u> operate on the principle of <u>stimulated emission</u> resulting from electron hole pair injection and direct <u>recombination</u> under forward bias." (Emphasis added) (http://materials.usask.ca/server/kasap/Dictionary/L.html, page 1 of 6) A copy of the web page containing this definition was sent in with the Applicant's office action response dated February 17, 2004.

"All lasers use the principle of amplification of electromagnetic waves by stimulated emission of radiation. The term laser is an acronym for light amplification by stimulated emission of radiation". (Lim *et al.*, US Patent 5,757,837, col. 1, lines 31–34).

. A necessary condition for stimulated emission is that "the electron and hole quasi–Fermi level separation exceed the photon energy. To achieve laser threshold, the gain must exceed the losses due to external emission plus the internal cavity losses such as free carrier absorption and scattering." (H.C. Casey, Jr., and M.B. Panish. "Heterostructure Lasers. Part A, Fundamental Properties". Academic Press, New York, p. 183). A copy of the relevant page of this reference was sent in with the Applicant's office action response dated February 17, 2004.

Amended claim 1 reads: "a semiconductor laser comprising: a) a bottom reflector; b) a top reflector; c) a cavity located between the bottom reflector and the top reflector; and d) an active region that can emit light; wherein the semiconductor laser can be operated in at least one resonant optical mode, such that: i) light is emitted from the active region; ii) light in the resonant optical mode propagates in the cavity in a direction tilted with respect to both a direction normal to a lateral plane and the lateral plane itself; iii) the resonant optical mode has minimum optical losses compared with optical losses of the other optical modes; and iv) a wavelength and a tilt angle of propagation of the light is stabilized".

Hanke *et al.* does not include a cavity and active region, with a resonant optical mode. Instead, Hanke *et al.* discloses light emitting diodes (LEDs) that emit incoherent radiation, which is present in a large number of optical modes. Moreover, selection of modes is not disclosed in Hanke *et al.* On the contrary, the LED is designed such that "as many modes as possible can propagate" (Abstract, line 5). The reflectivity of mirrors at the side facets, through which light comes out, are minimized to ensure an efficient extraction of light. Hanke *et al.* discloses neither selectivity in the angles of propagation of optical modes nor selectivity in the wavelength. In addition, there is no wavelength stabilization in Hanke *et al.*

In contrast, in claim 1, the semiconductor laser can be operated in at least one resonant optical mode such that light in the resonant optical mode propagates in the cavity in a direction tilted with respect to both a direction normal to a lateral plane and the lateral plane itself. In addition, the wavelength and the angle of propagation of the light is stabilized in claim 1, unlike in Hanke et al, where there is no stabilization.

The resonant optical mode is selected by the condition of the minimum losses, which for the lasers of claim 1 include radiative losses due to external emission through the side facets plus

the losses due to the emission of light through bottom and top reflectors. The means providing the selection of the optical modes with respect to the total losses include the particular design of multilayered interference reflectors and particular design of the cavity, as described in detail in the specification from page 15, line 27 through page 22, line 26. The wavelength selectivity is illustrated in Figures 6 through 14.

Reconsideration and withdrawal of the rejection of claim 1 is respectfully requested.

Claims 2, 4-13, 18-24, 58-63, and 85, being dependent upon and further limiting claim 1, should also be allowable for that reason, as well as for the additional recitations they contain. Reconsideration and withdrawal of the rejection of claims 2, 4-13, 18-24, 58-63, and 85 is respectfully requested.

Amended claim 91 reads: "a semiconductor device comprising: a) a bottom reflector; b) a top reflector; c) a cavity located between the bottom reflector and the top reflector; and d) an active region that can emit light; wherein the semiconductor device can be operated in at least one resonant optical mode, such that: i) light is emitted from the active region; ii) light in the resonant optical mode propagates in the cavity in a direction tilted with respect to both a direction normal to a lateral plane the lateral plane itself; iii) the resonant optical mode has minimum optical losses compared with optical losses of the other optical modes; and iv) a wavelength and a tilt angle of propagation of the light is stabilized".

Hanke *et al.* does not include a cavity and active region, where light in a resonant optical mode propagates in the cavity in a direction tilted with respect to both a direction normal to a lateral plane and the lateral plane itself. Instead, Hanke *et al.* discloses light emitting diodes (LEDs) that emit incoherent radiation, which is present in a large number of optical modes. Moreover, selection of modes is not disclosed in Hanke *et al.* On the contrary, the LED is designed such that "as many modes as possible can propagate" (Abstract, line 5). The reflectivity of mirrors at the side facets through which light comes out, are to be minimized to ensure an efficient extraction of light.

In contrast, in claim 91, the device includes a cavity bounded by two reflectors, where light in a resonant optical mode propagates within the cavity in a direction tilted with respect to

both the direction normal to the lateral plane and the lateral plane itself, and both a wavelength and an angle of propagation of the light is stabilized. This mode has a fixed selected angle of propagation within the cavity and a fixed wavelength. No selectivity is disclosed by Hanke *et al.* In addition, there is no stabilization in Hanke *et al.*

The resonant optical mode is selected by the condition of the minimum losses, which for the devices of claim 91 include radiative losses due to external emission through the side facets plus the losses due to the emission of light through bottom and top reflectors. The means providing the selection of the optical modes with respect to the total losses include the particular design of multilayered interference reflectors and particular design of the cavity, as described in detail in the specification from page 15, line 27 through page 22, line 26. The wavelength selectivity is illustrated in Figures 6 through 14. Reconsideration and withdrawal of the rejection of claim 91 is respectfully requested.

Claim 92, being dependent upon and further limiting claim 91, should also be allowable for that reason, as well as for the additional recitations it contains. Reconsideration and withdrawal of the rejection of claim 92 is respectfully requested.

11. Claims 1-6, 17-23, 25, 58-63, 85, 91, and 92 were rejected under 35 U.S.C. 102(b) as being anticipated by Magnusson *et al.* (6,154,480). Applicant respectfully disagrees.

A key requirement enabling the operation of the device disclosed in Magnusson *et al.* is a periodically modulated structure in a direction parallel to the surface. A crucial element of the invention in Magnusson *et al.* is guided mode resonance (GMR) mirrors. "The new VCL can be fabricated without Bragg mirrors by replacing them with efficient diffractive (guided–mode resonance (GMR)) mirrors with much fewer layers, for example, two or three layers. (Abstract, lines 3–7).

The key feature of GMR mirrors is that the refractive index is periodically modulated in the <u>lateral</u> direction. "The use of GMR mirrors fundamentally provides optical power flow not only across the active medium layer but also along the active region due to diffractive coupling" (col. 2, lines 47–50). Diffractive coupling occurs due to the refractive index modulation in the lateral plane and would not occur without such modulation.

Figures illustrating the embodiments of Magnusson *et al.* show the periodic modulation. These are Guided–Mode Resonance Mirror 22 in Fig. 2, periodically modulated structure in the inset of Fig. 3, p–type GMR Grating/Mirror 22' in Fig. 5, Guided–Mode Resonance Mirrors 32 and Guided–Mode Resonance Mirrors 22 in Fig. 6, Waveguide 33 including a periodically modulated structure in the lateral plane in Fig. 7, and GMR Mirror 22'' in Fig. 8.

"FIGS. 9–13 illustrate steps for making a GMR–VCL, using GaAs as an example material system, in accordance with the present invention." (col. 3, lines 28–30). These figures show a 250 nm photoresist layer (250–300 nm grating period) in Fig. 10, a ~100 nm thick etched grating layer in Fig. 11, a periodically modulated grating layer in Fig. 12 (not marked specifically), and a periodically modulated grating layer in Fig. 13 (not marked specifically), partially etched through. Fig. 15 schematically illustrates diffraction of a vertical optical mode into a propagating leaky mode in the lateral direction, and its diffraction back. A periodic grating comprising alternating regions marked in gray and white is shown and its period Λ is explicitly marked.

Thus, a periodic grating resulting in diffraction of light in the laser mode is required in Magnusson *et al.* "The photon gain paths characteristic of the GMR–VCL device are clearly shown in FIG. 5 by the arrows 26 & 28". (col. 5, lines 23–25). The arrows 26 point to the propagation of laser light in the vertical direction through the mirror, and the arrows 28 point to the propagation of the laser light in the lateral direction due to diffraction at the GMR–mirror. Referring to FIG. 7, the patent reads "[i]n this case, both GMR gratings and the active region are combined into a single periodic structure surrounded by appropriate waveguide 33 and the film spacer layers 35" (col. 5, lines 55–58). "As can be seen, the active region 24…has the same period as both the upper and lower GMR gratings." (col. 5, lines 62–63). "Coupled VCLs share a continuous resonant waveguide grating in the GMR mirrors." (col. 6, lines 11–13). In contrast, the present invention does not require a grating.

Magnusson *et al.* does not disclose constructing a wavelength-stabilized laser without a periodic structure in a direction in the surface plane, i.e., without a refractive index modulation in the surface plane. Distributed Bragg reflectors (DBRs) are calculated by Magnusson *et al.* to fit

the vertically propagating light in the cavity. No wavelength–stabilized operation without patterning in a lateral direction is disclosed by Magnusson.

In contrast, the present invention discloses constructing a semiconductor device, where the semiconductor device can be operated in at least one resonant optical mode such that light in the resonant optical mode propagates in the cavity in a direction tilted with respect to both a direction normal to the lateral plane and the lateral plane itself. This is the optical mode having minimum total losses, and the mode in which lasing occurs. The conditions of the minimum losses are met for a mode having a certain tilt angle and a certain wavelength. Thus, a wavelength-stabilized laser is constructed by a proper design of the cavity and reflectors, without any structure modulated in the lateral plane.

Regarding amended claim 1, the claim includes, in part, "c) a cavity located between the bottom reflector and the top reflector; and d) an active region that can emit light; wherein the semiconductor laser can be operated in at least one resonant optical mode, such that: i) light is emitted from the active region; ii) light in the resonant optical mode propagates in the cavity in a direction tilted with respect to both a direction normal to a lateral plane and the lateral plane itself; iii) the resonant optical mode has minimum optical losses compared with optical losses of the other optical modes; and iv) a wavelength and a tilt angle of propagation of the light is stabilized". Magnusson *et al.* does not disclose a cavity and active region, where the laser can be operated in at least one resonant optical mode such that light in the resonant optical mode propagates in the cavity in a direction <u>tilted</u> with respect to both a direction normal to the lateral plane and the lateral plane itself.

In Magnusson *et al.*, the necessary element for any selection of the optical modes is a periodically modulated structure in the lateral plane, i.e., in the p–n junction plane. On the contrary, in the present application, selection of a resonant tilted optical mode having a fixed tilt angle of propagation and a fixed wavelength, wherein the resonant optical mode has the minimum optical losses, is provided by the selection of the cavity and the reflectors, i.e. by the selection of a multilayered structure wherein the modulation of the refractive index occurs only in the vertical direction, i.e., in the direction normal to the p–n junction plane.

The Examiner points generally to Figs. 2, 5, 6 and 8-15 to support his assertion that claim 1 is anticipated by Magnusson *et al.* The Examiner does not specifically point to any portion of the patent when he states that the patent discloses the cavity and the active region being designed such that light propagates in the cavity in a direction tilted both normal to a lateral plane and with respect to the lateral plane. (see present office action dated July 29, 2004, page 6, lines 3-5).

Figs. 2, 5, 6 and 8-15 show various embodiments of the invention of Magnusson *et al.* "The new VCLs can be fabricated without Bragg mirrors by replacing them with efficient diffractive (guided-mode resonance (GMR)) mirrors with much fewer layers...." (Abstract). As shown in Fig. 5, the light output is normal to the substrate. Nowhere does the patent disclose a light in a resonant optical mode propagating in the cavity in a direction tilted with respect to both a direction normal to a lateral plane and the lateral plane itself. In addition, Magnusson *et al.* does not disclose a wavelength and an angle of propagation of light being stabilized. Therefore, claim 1 is not anticipated by Magnusson *et al.*

Reconsideration and withdrawal of the rejection of claim 1 is respectfully requested.

Claims 2-6, 17-23, 25, 58-63, and 85, being dependent upon and further limiting claim 1, should also be allowable for that reason, as well as for the additional recitations they contain. Reconsideration and withdrawal of the rejection of claims 2-15, 17-23, 25, 58-63, and 85 is respectfully requested.

Regarding amended claim 91, the claim includes, in part, "c) a cavity located between the bottom reflector and the top reflector; and d) an active region that can emit light; wherein the semiconductor device can be operated in at least one resonant optical mode, such that: i) light is emitted from the active region; ii) light in the resonant optical mode propagates in the cavity in a direction tilted with respect to both a direction normal to a lateral plane the lateral plane itself; iii) the resonant optical mode has minimum optical losses compared with optical losses of the other optical modes; and iv) a wavelength and a tilt angle of propagation of the light is stabilized". Magnusson *et al.* does not disclose a cavity and active region, where the device can be operated in at least one resonant optical mode such that light in the resonant optical mode propagates in the cavity in a direction tilted with respect to both a direction normal to the lateral plane and the lateral plane itself.

The Examiner points generally to Figs. 2, 5, 6 and 8-15 to support his assertion that claim 91 is anticipated by Magnusson *et al.* The Examiner does not specifically point to any portion of the patent when he states that the patent discloses the cavity and the active region being designed such that light propagates in the cavity in a direction tilted both normal to a lateral plane and with respect to the lateral plane. (see present office action dated July 29, 2004, page 6, lines 3-5).

Figs. 2, 5, 6 and 8-15 show various embodiments of the invention of Magnusson *et al.* "The new VCLs can be fabricated without Bragg mirrors by replacing them with efficient diffractive (guided-mode resonance (GMR)) mirrors with much fewer layers…." (Abstract). As shown in Fig. 5, the light output is normal to the substrate. Nowhere does the patent disclose a light in a resonant optical mode propagating in the cavity in a direction tilted with respect to both a direction normal to a lateral plane and the lateral plane itself. In addition, Magnusson *et al.* does not disclose a wavelength and an angle of propagation of light being stabilized. Reconsideration and withdrawal of the rejection of claim 91 is respectfully requested.

Claim 92, being dependent upon and further limiting claim 91, should also be allowable for that reason, as well as for the additional recitations it contains. Reconsideration and withdrawal of the rejection of claim 92 is respectfully requested.

12. Claims 1, 2, 4-13, 18, 24, 85, 86 and 91-95 were rejected under 35 U.S.C. 102(e) as being anticipated by Bewley *et al.* (U.S. Patent No. 6,643,305). Applicant respectfully disagrees.

Bewley *et al* clearly list the objects of their invention in the Summary of the invention: "to improve the efficiency of lasers that are optically pumped …" (col. 2, lines 64–65), "to improve the absorption of the pump energy in the active region" of an optically pumped laser" (col. 3, lines 1–3), "to lower the threshold pump intensity" (col. 3, lines 4–5), "to reduce the amount of cooling" (col. 3, lines 6–7), "to increase the temperature at which a high power laser can operate" (col. 3, lines 9–10), "to provide low cost, high power optically pumped edge emitting and surface emitting lasers" (col. 3, lines 11–12), "to provide high power optically pumped semiconductor lasers with high pump absorbance" (col. 3, lines 17–19), and "to provide lasers with a small number of quantum wells in the active region", (col. 3, lines 20–21).

In contrast, the tilted cavity laser disclosed in claim 1 provides wavelength-stabilized laser lasing. Claim 1 claims "a semiconductor laser comprising: a) a bottom reflector; b) a top reflector; c) a cavity located between the bottom reflector and the top reflector; and d) an active region that can emit light; wherein the semiconductor laser can be operated in at least one resonant optical mode, such that: i) light is emitted from the active region; ii) light in the resonant optical mode propagates in the cavity in a direction tilted with respect to both a direction normal to a lateral plane and the lateral plane itself; iii) the resonant optical mode has minimum optical losses compared with optical losses of the other optical modes; and iv) a wavelength and a tilt angle of propagation of the light is stabilized".

Bewley et al discloses an optically pumped laser, and tilted propagation of light is optionally used only for the pump light. This is very different from light in the resonant optical mode propagating in the cavity in a direction tilted with respect to both a direction normal to a lateral plane and the lateral plane itself.

Bewley *et al.* present a relationship between the wavelength and the tilt angle for the pump light (Equation 1 of Bewley *et al.*, col. 4, line 61–62). However, such a relationship does not provide a resonant optical mode, such that two quantities, namely both a wavelength and an angle of propagation of the light is stabilized. It provides a wavelength as a function of an angle, or vice versa, an angle as a function of a wavelength. Moreover, this is done intentionally as "Should exact control over the distance between the mirrors be difficult to achieve, resonance can be attained by varying either the wavelength or the incident angle of the pump radiation." (col. 5, lines 12–15).

Bewley *et al.* give no indication that the design of reflectors depends on the required angle of incidence for the pumped light. The reflectors are only specified as distributed Bragg reflectors. Those skilled in the art know that distributed Bragg reflectors are commonly selected for the propagation of light in the direction normal to the p-n junction. Claim 17 by Bewley *et al.* reads "A laser as in claim 16, wherein the alternating layers of said distributed Bragg reflector has have an optical thickness of $1/4\lambda_p$" (col. 18, lines 36-38). Such selection of the thicknesses of layers refers again to the fact that the reflector is optimized for the normal propagation of light.

Bewley *et al.* does not disclose a laser that can generate laser light in a resonant optical mode, such that the generated laser light in the resonant optical mode propagates within the cavity in a direction tilted with respect to both the direction normal to the lateral plane and to the lateral plane itself, and a wavelength and an angle of propagation of the generated laser light are stabilized. Claim 1 is therefore not anticipated by Bewley *et al.* Reconsideration and withdrawal of the rejection of claim 1 is respectfully requested.

Claims 2, 4-13, 18, 24, 85, 86 and 93-95, being dependent upon and further limiting claim 1, should also be allowable for that reason, as well as for the additional recitations they contain. Reconsideration and withdrawal of the rejection of claims 2, 4-13, 18, 24, 85, 86 and 93-95 is respectfully requested.

Claim 91 provides a wavelength-stabilized device. Claim 91 claims "a semiconductor device comprising: a) a bottom reflector; b) a top reflector; c) a cavity located between the bottom reflector and the top reflector; and d) an active region that can emit light; wherein the semiconductor device can be operated in at least one resonant optical mode, such that: i) light is emitted from the active region; ii) light in the resonant optical mode propagates in the cavity in a direction tilted with respect to both a direction normal to a lateral plane the lateral plane itself; iii) the resonant optical mode has minimum optical losses compared with optical losses of the other optical modes; and iv) a wavelength and a tilt angle of propagation of the light is stabilized".

Bewley et al discloses an optically pumped laser, and tilted propagation of light is optionally used only for the pump light. This is very different from the device in claim 91, where light in the resonant optical mode propagating in the cavity in a direction tilted with respect to both a direction normal to a lateral plane and the lateral plane itself, and both the tilt angle of propagation and the wavelength are stabilized.

Bewley *et al.* present a relationship between the wavelength and the tilt angle for the pump light (Equation 1 of Bewley *et al.*, col. 4, line 61–62). However, such a relationship does not provide a resonant optical mode, such that the two quantities at the same time, namely both a wavelength and an angle of propagation of the light is stabilized. It provides a wavelength as a function of an angle, or vice versa, an angle as a function of a wavelength. Moreover, this is done

intentionally as "Should exact control over the distance between the mirrors be difficult to achieve, resonance can be attained by varying either the wavelength or the incident angle of the pump radiation." (Bewley *et al.*, col. 5, lines 12–15).

Bewley *et al.* give no indication that the design of reflectors depends on the required angle of incidence for the pumped light. The reflectors are only specified as distributed Bragg reflectors. Those skilled in the art know that distributed Bragg reflectors are commonly selected for the propagation of light in the direction normal to the p-n junction. Claim 17 by Bewley *et al.* reads "A laser as in claim 16, wherein the alternating layers of said distributed Bragg reflector has have an optical thickness of $1/4\lambda_p$".

Bewley *et al.* does not disclose a device that can operate in a resonant optical mode, such that two quantities at the same time, namely both a wavelength and an angle of propagation are stabilized. Claim 91 is therefore not anticipated by Bewley *et al.* Reconsideration and withdrawal of the rejection of claim 91 is respectfully requested.

Claim 92, being dependent upon and further limiting claim 91, should also be allowable for that reason, as well as for the additional recitations it contains. Reconsideration and withdrawal of the rejection of claim 92 is respectfully requested.

Rejections under 35 U.S.C. §103

14. Claim 16 was rejected under 35 U.S.C. 103(a) as being unpatentable over Lim *et al.* Applicant respectfully disagrees. The arguments regarding the anticipation of claim 1, upon which claim 16 depends, are incorporated herein.

As discussed above, claim 1, upon which claim 16 depends, is not anticipated by Lim *et al.* Similarly, claim 1 is not obvious over Lim *et al.* Lim *et al.* does not teach or suggest a cavity and an active region, where the semiconductor laser can be operated in at least one resonant optical mode such that light in the resonant optical mode propagates in the cavity in a direction tilted with respect to both a direction normal to a lateral plane and the lateral plane itself. Therefore, claim 1 is not obvious over Lim *et al.*

Regarding claim 16, the Examiner admits that Lim *et al.* does not teach "the optical aperture being made by partial selective removal of several layers of the top reflector." (present office action dated July 29, 2004, page 7, lines 13-14). However, the Examiner continues by stating it would be an obvious matter of design choice to use any known method in the art to make an optical aperture. The Examiner provides no support for this statement. Instead, the Examiner states that "applicant has not disclosed that partial selective removal solves any stated problem or is for any particular purpose and it appears that the invention would perform equally well with an additional layer add[ed] on top of the reflector." (present office action dated July 29, 2004, page 7, lines 16-18).

In the United States, the standard of obviousness has no relation to whether or not the elements claimed solved any stated problem or is for any particular purpose. Even if the invention would perform equally well with an additional layer added on top of the reflector (which the Applicants do not concede), that is irrelevant to whether or not claim 16 is obvious. Amended claim 16 is a dependent claim, which adds a limitation to claim 1, upon which it depends. Instead, in order for the Examiner to make a valid argument for obviousness, he must show that the reference or references, alone or in combination, teach or suggest all of the elements in the claim. The Examiner admits that Lim *et al.* does not teach or suggest the elements of claim 16.

"The deficiencies of the cited references cannot be remedied by... general conclusions about what is "basic knowledge" or "common sense" to one of ordinary skill in the art.... With respect to core factual findings in a determination of patentability,... the... [Examiner] cannot simply reach conclusions based on its own understanding or experience - or on its assessment of what would be basic knowledge or common sense. Rather, the... [Examiner] must point to some concrete evidence in the record in support of these findings." *In re Zurko*, 59 USPQ2d 1693, 1697 (Fed. Cir. 2001).

In addition, the Federal Circuit has held that the Examiner must identify the specific principle or objective teaching that would suggest the claimed combination. *see In re Lee*, 61 USPQ2d 1430, 1433-1435 (Fed. Cir. 2002). Unspecified common sense and common

knowledge is not sufficient for obviousness. *see id.* The Patent Office is obligated to develop an evidentiary basis for its findings. *See id.*

The Examiner has not provided concrete evidence to support his assertions that partial selective removal of several layers of the top reflector is an obvious matter of design choice. Nor has he provided a specific principle or objective teaching to suggest the claimed combination of claim 16. Therefore, claim 16 is not obvious over Lim *et al.*

Claim 16, being dependent upon and further limiting claim 1, should also be allowable for that reason, as well as for the additional recitations it contains. Reconsideration and withdrawal of the rejection of claim 16 is respectfully requested.

15. Claims 16 and 26 were rejected under 35 U.S.C. 103(a) as being unpatentable over Magnusson *et al.* Applicant respectfully disagrees. The arguments regarding the anticipation of claim 1, upon which claims 16 and 26 depend, are incorporated herein.

As discussed above, claim 1, upon which claims 16 and 26 depend, is not anticipated by Magnusson *et al.* Similarly, claim 1 is not obvious over Magnusson *et al.* does not teach or suggest a cavity and an active region, where the semiconductor laser can be operated in at least one resonant optical mode such that light in the resonant optical mode propagates in the cavity in a direction tilted with respect to both a direction normal to a lateral plane and the lateral plane itself. Therefore, claim 1 is not obvious over Magnusson *et al.*

Regarding claim 16, the Examiner admits that Magnusson *et al.* does not teach "the optical aperture being made by partial selective removal of several layers of the top reflector." (present office action dated July 29, 2004, page 7, lines 22-23). However, the Examiner continues by stating it would be an obvious matter of design choice to use any known method in the art to make an optical aperture. The Examiner provides no support for this statement. Instead, the Examiner states that "applicant has not disclosed that partial selective removal solves any stated problem or is for any particular purpose and it appears that the invention would perform equally well with an additional layer add[ed] on top of the reflector." (present office action dated July 29, 2004, page 8, lines 1-4).

In the United States, the standard of obviousness has no relation to whether or not the elements claimed solved any stated problem or is for any particular purpose. Even if the invention would perform equally well with an additional layer added on top of the reflector (which the Applicants do not concede), that is irrelevant to whether or not claim 16 is obvious. Amended claim 16 is a dependent claim, which adds a limitation to claim 1, upon which it depends. Instead, in order for the Examiner to make a valid argument for obviousness, he must show that the reference or references, alone or in combination, teach or suggest all of the elements in the claim. The Examiner admits that Magnusson *et al.* does not teach or suggest the elements of claim 16.

"The deficiencies of the cited references cannot be remedied by... general conclusions about what is “basic knowledge” or “common sense” to one of ordinary skill in the art.... With respect to core factual findings in a determination of patentability,... the... [Examiner] cannot simply reach conclusions based on its own understanding or experience - or on its assessment of what would be basic knowledge or common sense. Rather, the... [Examiner] must point to some concrete evidence in the record in support of these findings." *In re Zurko*, 59 USPQ2d 1693, 1697 (Fed. Cir. 2001).

In addition, the Federal Circuit has held that the Examiner must identify the specific principle or objective teaching that would suggest the claimed combination. *see In re Lee*, 61 USPQ2d 1430, 1433-1435 (Fed. Cir. 2002). Unspecified common sense and common knowledge is not sufficient for obviousness. *see id.* The Patent Office is obligated to develop an evidentiary basis for its findings. *See id.*

The Examiner has not provided concrete evidence to support his assertions that partial selective removal of several layers of the top reflector is an obvious matter of design choice. Nor has he provided a specific principle or objective teaching to suggest the claimed combination of claim 16. Therefore, claim 16 is not obvious over Magnusson *et al.*

Claim 16, being dependent upon and further limiting claim 1, should also be allowable for that reason, as well as for the additional recitations it contains. Reconsideration and withdrawal of the rejection of claim 16 is respectfully requested.

Regarding claim 26, the Examiner admits that Magnusson *et al.* does not teach a grating fabricated above the top reflector, where the grating provides a distributed feedback in a lateral direction. However, the Examiner continues by stating it would be an obvious matter of design choice to any known element in the art that provides a distributed feedback in a lateral direction. The Examiner provides no support for this statement. Instead, the Examiner states that "applicant has not disclosed that a grating fabricated above the top reflector solves any stated problem or is for any particular purpose and it appears that the invention would perform equally well with the top reflector being partially etched." (present office action dated November 20, 2003, page 11, lines 5-7).

In the United States, the standard of obviousness has no relation to whether or not the elements claimed solved any stated problem or is for any particular purpose. Even if the invention would perform equally well with the top reflector being partially etched (which the Applicants do not concede or deny), that is irrelevant to whether or not claim 26 is obvious. Claim 26 is a dependent claim, which adds a limitation to claim 1, upon which it depends.

In order for the Examiner to make a valid argument for obviousness, he must show that the reference or references, alone or in combination, teach or suggest all of the elements in the claim. The Examiner admits that Magnusson *et al.* does not teach or suggest the elements of claim 26.

"The deficiencies of the cited references cannot be remedied by... general conclusions about what is "basic knowledge" or "common sense" to one of ordinary skill in the art.... With respect to core factual findings in a determination of patentability,... the... [Examiner] cannot simply reach conclusions based on its own understanding or experience - or on its assessment of what would be basic knowledge or common sense. Rather, the... [Examiner] must point to some concrete evidence in the record in support of these findings." *In re Zurko*, 59 USPQ2d 1693, 1697 (Fed. Cir. 2001).

In addition, the Federal Circuit has held that the Examiner must identify the specific principle or objective teaching that would suggest the claimed combination. *see In re Lee*, 61 USPQ2d 1430, 1433-1435 (Fed. Cir. 2002). Unspecified common sense and common

knowledge is not sufficient for obviousness. *see id.* The Patent Office is obligated to develop an evidentiary basis for its findings. *See id.*

The Examiner has not provided concrete evidence to support his assertions that a grating fabricated above the top reflector is an obvious matter of design choice. Nor has he provided a specific principle or objective teaching to suggest the claimed combination of claim 26. Therefore, claim 26 is not obvious over Magnusson *et al.*

Claim 26, being dependent upon and further limiting claim 1, should also be allowable for that reason, as well as for the additional recitations it contains. Reconsideration and withdrawal of the rejection of claim 26 is respectfully requested.

16. Claim 26 was rejected under 35 U.S.C. 103(a) as being unpatentable over Hanke *et al.* Applicant respectfully disagrees. The arguments regarding the anticipation of claim 1, upon which claim 26 depends, are incorporated herein.

As discussed above, claim 1, upon which claim 26 depends, is not anticipated by Hanke *et al.* Similarly, claim 1 is not obvious over Hanke *et al.* Hanke *et al.* discloses a light emitting diode (LED) which emits incoherent light in a broad spectral range. No means to provide emission of light in one resonant optical mode is taught or suggested. Hanke *et al.* does not teach or suggest a cavity and an active region designed such that any of the optical modes is a resonant optical mode. Therefore, claim 1 is not obvious over Hanke *et al.*

Regarding claim 26, the Examiner admits that Hanke *et al.* does not teach a grating fabricated above the top reflector, where the grating provides a distributed feedback in a lateral direction. However, the Examiner continues by stating it would be an obvious matter of design choice to any known element in the art that provides a distributed feedback in a lateral direction. The Examiner provides no support for this statement. Instead, the Examiner states that "applicant has not disclosed that a grating fabricated above the top reflector solves any stated problem or is for any particular purpose and it appears that the invention would perform equally well with the top reflector being partially etched." (present office action dated July 29, 2004, page 8, lines 18-21).

In the United States, the standard of obviousness has no relation to whether or not the elements claimed solved any stated problem or is for any particular purpose. Even if the invention would perform equally well with the top reflector being partially etched (which the Applicants do not concede), that is irrelevant to whether or not claim 26 is obvious. Claim 26 is a dependent claim, which adds a limitation to claim 1, upon which it depends.

In order for the Examiner to make a valid argument for obviousness, he must show that the reference or references, alone or in combination, teach or suggest all of the elements in the claim. The Examiner admits that Hanke *et al.* does not teach or suggest the elements of claim 26.

"The deficiencies of the cited references cannot be remedied by… general conclusions about what is "basic knowledge" or "common sense" to one of ordinary skill in the art…. With respect to core factual findings in a determination of patentability,… the… [Examiner] cannot simply reach conclusions based on its own understanding or experience – or on its assessment of what would be basic knowledge or common sense. Rather, the… [Examiner] must point to some concrete evidence in the record in support of these findings." *In re Zurko*, 59 USPQ2d 1693, 1697 (Fed. Cir. 2001).

In addition, the Federal Circuit has held that the Examiner must identify the specific principle or objective teaching that would suggest the claimed combination. *See In re Lee*, 61 USPQ2d 1430, 1433-1435 (Fed. Cir. 2002). Unspecified common sense and common knowledge is not sufficient for obviousness. *See id.* The Patent Office is obligated to develop an evidentiary basis for its findings. *See id.*

The Examiner has not provided concrete evidence to support his assertions that a grating fabricated above the top reflector is an obvious matter of design choice. Nor has he provided a specific principle or objective teaching to suggest the claimed combination of claim 26. Therefore, claim 26 is not obvious over Hanke *et al.*

Claim 26, being dependent upon and further limiting claim 1, should also be allowable for that reason, as well as for the additional recitations it contains. Reconsideration and withdrawal of the rejection of claim 26 is respectfully requested.

Conclusion

Applicant believes the claims, as amended, are patentable over the prior art, and that this case is now in condition for allowance of all claims therein. Such action is thus respectfully requested. If the Examiner disagrees, or believes for any other reason that direct contact with Applicants' attorney would advance the prosecution of the case to finality, he is invited to telephone the undersigned at the number given below.

"Recognizing that Internet communications are not secured, I hereby authorize the PTO to communicate with me concerning any subject matter of this application by electronic mail. I understand that a copy of these communications will be made of record in the application file."

Respectfully Submitted:
Ledentsov et al.

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